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Coating Calculations

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7.1 Introduction

Coatings are defined as mixtures of various materials. The questions arise as to how much of which materials, and how do these things relate. The materials fall into four general categories, as follows:

- Resins
- Pigments
- Solvents
- Additives

7.2 Resins

These are the generally solid, sticky materials that hold the system together. They are also called binders, and when in a solvent, they are the vehicles for the system. They may come as a "single-package" or "two-package" system. Single package is just the liquid resin or the resin in solvent. Two package means that an "A" part was blended with a "B" part to cause a chemical reaction. In both systems, we need to know the amount of solid resin present. This dry material divided by the total of the dry plus the solvent is frequently called a "resin solid." With the two-package systems, we need to know not only the solids but also the ratio of these solids to form the desired film. This ratio may be designated as a simple ratio of 1 to 1. Or it may be based on 1 or 100, as 0.3 to 1, or 30 parts per hundred, or a total of 100 as 43 to 57. These ratios determine the film properties. We will also need to know the density (weight per unit volume, usually as pounds per gallon) of the resin or vehicle to help calculate volume.

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7.3 Pigments

Pigments are the dry materials added to the coating to give it color or resistance properties, camouflaging properties, and the like. Pigments can be divided into many different categories for different purposes. Some materials are primary pigments versus filler pigments. Some materials are organic in nature, and others are inorganic. Properties such as lightfastness, particle size, and specific color are reasons for choice. For calculation purposes, dry density and evaporative material are needed for each pigment.

7.4 Solvents

The materials that permit you to apply the coating in a liquid state are called solvents. Solvents may be organic; they may even be water. They are in the formulation to aid in mixing, viscosity, and application of the coating. After application, they evaporate and leave a dry film. For calculation purposes, the density needs to be known.

7.5 Additives

These are ingredients added in small (<5%) amounts to alter some properties of the coating. They must be included in the calculation, as they have both solids and density factors that must be accounted for.

7.6 Conventions

The relationships among the various ingredients are looked at in the two aspects of weight and volume. Each aspect not only tells of the relationship but also implies some property of the formulation. Experienced formulators may use many of the relationships interchangeably, as they have a deep understanding of the processes. Common practice many years ago was to manufacture paint in 100 gallon batches. Ingredients were then spoken of as "pounds per 100 gallons." However, if the batch was not 100 gallons, then the ingredients were spoken of as "pounds per gallon." Consequently, statements such as "it has 100 pounds of pigment already" and "well, lets take it up to 2 pounds" make sense when one understands the practice of interchanging the basis for the number.

The density (weight per unit volume) of material is usually used as pounds per gallon. To convert numbers to a volume measurement (volume per unit weight) or "bulking factor," divide the density into 1.

$$\text{Bulking factor} = 1/(\text{Density as pounds/gallon})$$

7.7 Calculations

To begin, list the ingredients of the formulation. From the supplier of the material, get the density, the nonvolatile level, and the price of each ingredient. Make a list as shown in Table 7.1. Calculate the bulking factor (gallons/pound). Based on your knowledge, experience, and laboratory testing, you will estimate a rough relationship of ingredients, probably by weight.

7.7.1 Formulation Weight

Add the ingredients you have considered or used in the formulation (530 pounds).

7.7.2 Formulation Volume

Multiply the weight of each ingredient by its bulking factor. This will give the volume of the weight used. Total this column (50.97 gallons).

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TABLE 7.1 Paint Formulation Calculations

		Constants				Calculations						
No.	Material	lb/gal	gal/lb	%NV	Cost, $/lb	Weight	Volume	Dry Weight	Dry Volume	#/100 gal	gal/100 gal	Cost/gal
1	Titanium Dioxide	34.99	0.029	100	$1.15	100	2.86	100	2.86	196.00	5.6	2.25
2	Phthalocyanine Blue	12.99	0.077	100	$10.55	50	3.85	50	3.85	98.00	7.5	10.34
3	Acrylic Resin Solution	9.05	0.11	50	$1.09	300	33.15	150	16.58	588.00	65.0	6.41
4	Toluene	7.55	0.132	0	$0.28	20	2.65	0		39.20	5.2	0.11
5	Butoxyethanol	7.51	0.133	0	$0.75	30	3.99	0	0	58.80	7.8	0.44
6	Methyl Ethyl Ketone	6.71	0.149	0	$0.55	30	4.47	0	0	58.80	8.8	0.32
7												
8												
9												
10												
	Total	X	X	X	X	530	50.97	300	23.29	1038.8	99.9	19.88
						Factor = 1.96						
	On Total Formulation											
a	% Nonvolatile Weight					56.60						
b	% Nonvolatile Volume						45.69					
c	Pigment/Binder Ratio					2 to 3						
d	Pigment Volume Content						28.81					
e	Density, lb/gal					10.4						
f	square feet/gal @ 1 mil dry									733		

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7.7.3 Formulation Density

Dividing the formulation weight by the formulation volume gives the density of the formulation (10.4 pounds/gallon).

7.7.4 Formulation of "Nonvolatile by Weight"

Multiply the weight of each ingredient by its nonvolatile content, and total the column (300 pounds). Divide this total by the formulation weight, 530 pounds, to get 0.5660, and multiply by 100 to get 56.6% NV-WT.

7.7.5 Formulation "Nonvolatile by Volume"

Multiply the volume of each ingredient by its nonvolatile content, and total the column (23.29 gallons). Divide this total by the formulation volume (50.97 gallons) to get 0.4569, and multiply by 100 to get 45.69% NV-VOL.

7.7.6 Pigment to Binder Ratio (Weight)

The pigment to binder ratio is a weight relationship, and depending on the formulator's background, it can be expressed in several mathematical ways:

$$\text{Direct Ratio: pigment to binder} = 1/1$$

$$\text{Percentage: pigment to binder} = \text{pigment}/\text{pigment} + \text{binder} = 1/1 + 1 = 0.50$$

$$\text{Parts: Parts of pigment per 1 or 100 parts of resin} = 100/100$$

7.7.7 Pigment Volume Content (Volume)

The standard abbreviation is "PVC," which should not be interpreted as polyvinyl chloride or any other item. This is a volume relationship expressed as a percentage:

$$\text{Pigment volume content (PVC, \%)} = [(\text{Volume of the pigments})/(\text{Volume of the pigments} + \text{Volume of the binder})] \times 100$$

$$\text{PVC} = ((2.86 + 3.85)/23.29) \times 100 = 28.81\%$$

The volume relationship of the pigment to the binder appears to be a more critical number. Studies have shown that there is a point at which the level of pigment in a given system is high enough to cause deterioration of the film produced. This point is termed the "critical pigment volume content" (CPVC).

7.8 Converting to a 100 Gallon Formulation

To convert the initial formulation to a 100 gallon basis, divide the initial volume (50.97 gallons) into 100 gallons to get a factor (1.96). Multiply this factor by the weight of each ingredient in the initial formulation to get pounds in 100 gallons. Multiply the factor by the volume of each ingredient in the initial formulation to get gallons per 100 gallons. If the amount to be manufactured is something other than 100 gallons, divide the desired volume by the initial volume to get a factor, and multiply as above.

7.9 Cost

Multiply the cost ($/pound) of each ingredient times the weight in the pounds/100 gallon formulation, and divide by 100 to get the cost of the ingredient. Total the column for cost per gallon ($/gallon).

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7.10 Coverage

Frequently, the question arises as to how much a gallon will cover. A 1 gallon volume will cover 1604 square feet at 1 wet mil (0.001 inches), assuming no loss of any type. If the paint were 50% volume solids, this would give a film thickness of 0.5 mil. On the other hand, if I wanted a 2 mil dry film from a 50% volume solids paint, I would have to apply the paint at 4 wet mils per gallon, or 400 square feet per gallon. The standard is 1 mil dry. In the example, $1604 \times 0.4569 = 733$ square feet per gallon.

7.11 Computer Use

With the use of computers, calculating formulations may be done easier and faster. There are commercial computer programs that are available. Using a spreadsheet, a personalized calculation may be designed. Table 7.2 is an example of spreadsheet use. It shows the "constants" of the ingredients, which must be known, and the "calculations." This approach can be used for either solvent-borne or water-borne systems. Because costs vary widely, the numbers have been left out, but room is provided to use them.

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TABLE 7.2 Paint Formulation

		Constants						Calculations								
No.	Material	lb/gal	gal/lb	%NV	% Solvent	% Water	Cost, $/lb	Weight	Gallons	Dry Wt	Dry Vol	#/100 gal	gal/100#	Cost/ 100 gal	Water	Solvent
1	Gloss Varnish	8.43	0.118623962	1	0	0	$0.00	75	8.896797153	75.00	8.896797153	347.76	41.25	$0.00	0	0
2	Resin @ 40% in BCarbAc	8.71	0.114810563	0.4	0.6	0	$0.00	25	2.870264064	10.00	1.148105626	115.92	13.31	$0.00	0	69.55284525
3	Titanium Dioxide	10.5	0.095238095	1	0	0	$0.00	95	9.047619048	95.00	9.047619048	440.50	41.95	$0.00	0	0
4	Antiskin Agent	13	0.076923077	1	0	0	$0.00	0.1	0.007692308	0.10	0.007692308	0.46	0.04	$0.00	0	0
5	Butyl Carbitol Acetate	10.8	0.092592593	0	1	0	$0.00	7.4	0.685185185	0.00	0	34.31	3.18	$0.00	0	34.31273699
6	Cobalt Drier, 6%	17.83	0.05608525	0.5	0.5	0	$0.00	0.253	0.014189568	0.13	0.007094784	1.17	0.07	$0.00	0	0.586562328
7	Lead Drier, 12%	8.5	0.117647059	0.5	0.5	0	$0.00	0.379	0.044588235	0.19	0.022294118	1.76	0.21	$0.00	0	0.878684278
8										0.00	0	0.00		$0.00	0	0
9										0.00	0	0.00		$0.00	0	0
10										0.00	0	0.00		$0.00	0	0
	Total	X	X	X		X	X	203.132	21.56633556	180.42	19.12960304	941.89	100.00	$0.00	0	105.3308289
	Total Formulation							factor = 4.63685635					cost/gal			
	lb/gal	9.42												$0.00		
	% Nonvolatile weight									88.817						
	% Nonvolatile volume								88.701				for loss $@95$			
	Pigment/Binder Ratio			0.51										$0.00		
	wt pigment			95												
	wt binder			90												
	Pigment Volume Content			0.22												
	vol pigment			2.87												
	vol binder			10.05												
	vol pigment + binder															
	% Water	0.00		VOC = 1.05 lbs/gal												
	% Solvent	11.18														

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